

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Commissioner
 US Department of Commerce
 United States Patent and Trademark
 Office, PCT
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 CP2/5C24
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 in its capacity as elected Office

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International filing date (day/month/year) 01 September 2000 (01.09.00)	Priority date (day/month/year) 02 September 1999 (02.09.99)
Applicant GRAYDEN, David, Bruce et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:
 15 March 2001 (15.03.01)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer Claudio Borton Telephone No.: (41-22) 338.83.38
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



WO-01/19135 A1

(54) Title: IMPROVED SOUND PROCESSOR FOR COCHLEAR IMPLANTS

(57) Abstract: An improved sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for processing the sounds and converting them to electrical stimulation signals for application to the electrodes of the cochlear implant for stimulation of the auditory nerve, said sound processing means including means for generating electrical signals to be applied to the basal electrodes having different predetermined rates of stimulation and the implant having basal electrodes and apical electrodes and the means for generating electrical signals to be applied to the apical electrodes have a different rate of stimulation, the electrical signals to be applied to the basal electrodes having a higher rate of stimulation than the electrical signals to be applied to the apical electrodes.

IMPROVED SOUND PROCESSOR FOR COCHLEAR IMPLANTS

Field of the Invention

This invention relates to improvements in sound processors for cochlear implants, and more particularly to a Differential Rate Sound Processor (DRSP)

Background of the Invention

The multi-channel cochlear implant was first implanted in 1978. Early signal processing designs extracted the second formant (F2) and pitch (F0) to control electrode stimulation. The frequency of F2 controlled the location of electrode stimulation, and F0 controlled the rate of stimulation. This was later improved by also extracting the first formant (F1) and adding a second stimulated electrode for each pitch period. The MULTI-PEAK (MPEAK) stimulation strategy added stimulation of a number of fixed electrodes to better represent high-frequency information. The next stages of development were the SMSP and SPEAK strategies. These were a departure from the others at they used a fixed stimulation rate and stimulated electrodes that corresponded to maxima in the sound spectra. Another fixed-rate strategy, CIS, was developed overseas. This strategy stimulated all of a small number of electrodes to represent the sound spectra. All of the above processing strategies involve fixed-rate sound processing.

The named inventors have determined that some speech features are better perceived using low-rates of simulation, while some are better perceived using high rates of stimulation. Higher rates of stimulation present more information about phonetic manner of articulation, but spectral information tends to be smeared at such higher rates.

Summary of the Invention and Object

It is an object of the present invention to provide an improved sound processor for use with cochlear implants in which the problems associated with fixed rate stimulation are ameliorated.

The invention provides in one form an improved sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for processing the sounds and converting them to electrical stimulation signals for application to the electrodes of the cochlear implant for stimulation of the auditory nerve, said sound processing means including means for generating electrical signals to be applied to the electrodes having different predetermined rates of stimulation.

In this first form of the invention, the cochlear implant preferably has basal electrodes and apical electrodes and the means for generating electrical signals to be applied to the apical electrodes have a different rate of stimulation, the electrical signals to be applied to the basal electrodes having a higher rate of stimulation than the electrical signals to be applied to the apical electrodes.

By causing stimulation of the basal electrodes at a higher rate of stimulation than the apical electrodes, the manner of articulation features of speech will be more optimally presented to the cochlear implant user, leading to improved speech understanding performance. High rates of stimulation at the basal electrodes will present good information about temporal events and friction. The low rates of stimulation of the apical electrodes will present good spectral information in this regard, where most place of articulation features reside.

In a preferred embodiment, the more apical electrodes will be chosen as those that contain the voice bar and lower formants of speech. In this frequency region, spectral detail is important and the apical electrodes will be stimulating using a stimulation rate of between about 250 cycles per second and about 800 cycles per second, depending on the user. By adopting stimulation rates falling within the above range, better information about place of articulation of speech, which is largely represented by the formant structure, is obtained by the user.

The more basal electrodes represent higher frequency components of the incoming sound, and higher rates of stimulation of these electrodes will be used

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to better represent noise and more precisely present information about temporal events such as rapid changes in amplitude. The latter is important for perception of manner of articulation and voicing. These electrodes will be stimulated at a higher rate than the apical electrodes, with stimulation rates at or above about
5 800 cycles per second, and preferably up to about 1600 cycles per second, being selected depending on the user.

In the case of an implant having 20 electrodes available for stimulation, the apical electrodes are electrodes 0 to 12, and the basal electrodes are electrodes 13 to 19. The apical electrodes represent sound frequencies from 0 to
10 about 2700Hz, while the basal electrodes represent frequencies from about 2700Hz to about 7900Hz. The stated apical electrode frequencies are sufficient to contain the first three formants of most speech.

In a particularly preferred form of the invention, the apical electrodes are stimulated at about 250 cycles per second while the basal electrodes are
15 stimulated at about 1500 cycles per second. To ensure that stimulation levels are suitable for these different rates, the threshold (T) levels and comfort (C) levels of the patient are carefully set. The electrodes to be stimulated are chosen by selecting the eight largest spectral energies within filterbanks derived from the Fast Fourier Transform (FFT) or the Discrete Wavelet Transform (DWT)
20 which is performed by the processor.

In another form, the invention provides an improved sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for processing the sounds and converting to electrical stimulation signals for application to the electrodes of
25 the cochlear implant whereby the auditory nerve is electrically stimulated, said sound processing means having means for varying the rate of stimulation of the electrical stimulation signals depending on the parameters of the sound received by the sound receiving means.

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By varying the rate of stimulation of the cochlear implant electrodes depending on the incoming speech signal, key speech features will be more optimally presented to the cochlear implant user thereby leading to improved speech understanding performance.

5 In a preferred form of this aspect of the invention, the sound processing means will be programmed to continually adjust the rate of stimulation of the electrical stimulation signals depending on the parameters of the incoming speech signal. To this end, the incoming speech signal will be processed to detect events that are better represented using a higher rate of stimulation. Such
10 events include plosive onset bursts, frication and other rapid spectral changes. The rate of stimulation across all electrodes will be increased for the average duration of these events. The standard rate will be between 250 cycles/s and 800 cycles/s depending on the user. The higher rate will be above about 800 cycles/s, and preferably up to about 1600 cycles/s, also depending on the user.

15 In order that the invention may be more readily understood, one presently preferred embodiment of the invention will now be described.

Description of Preferred Embodiment

The invention is preferably designed for use with the CI-24M Cochlear Implant as manufactured by Cochlear Ltd, and as described in US Patent No.
20 4532930, the contents of which are incorporated herein by cross-reference, and later patents by Cochlear Ltd to be found in the patent literature.

Although the CI-24M Implant will be used in most cases, the invention could be applied to any implant that uses pulsatile stimulation. The stimulation strategy is based on the Spectral Maxima Sound Processor (SMSP), which is
25 described in United States Patent 5597380 and Australian Patent 657959, the contents of which are incorporated herein by cross reference although other strategies may be used with similar results. For example, the SPEAK strategy as discussed in US Patent No. 5,597,380, the contents of which are incorporated by cross reference.

The electrode selection strategy from the SMSP is varied to ensure that electrodes are stimulated at the desired predetermined frequencies for each cycle of stimulation. The preferred signal processing device will be the SPEAR processor, which is currently under development at The Bionic Ear Institute, and
5 which is described in the following paper :

Zakis, J.A. and McDermott, H.J. (1999). "A new digital sound processor for hearing research," Proceedings of the Inaugural Conference of the Victorian Conference of the Victorian Chapter of the IEEE Engineering in Medicine and Biology Society, February 22-23, pp. 54-57. The contents of this paper are
10 similarly incorporated herein by cross reference.

The processor is a generic processor based on the Motorola DSP56300 family, such as the DSP56302, or the DSP56309, although any digital signal processor, including those produced by Cochlear Ltd and their competitors, could be used to run the differential rate sound processor program of the present
15 invention, provided they have adequate processing speed.

In the implementation of the first form of the invention, the differential rate stimulation processor software embodying the invention is downloaded to the SPEAR processor and stored on EPROM. Patient map details, including frequency bands, threshold (T) levels and comfort (C) levels, are also stored on
20 the device. Monopolar stimulation mode is used to reduce current levels and for longer battery life.

For the case where 20 electrodes are available for stimulation, the apical electrodes are electrodes 0 to 12, and the basal electrodes are electrodes 13 to 19. The apical electrodes then represent frequencies from 0 to 2700Hz; the
25 basal electrodes represent frequencies from 2700Hz to 7900Hz. The stated apical electrode frequencies are sufficient to contain the first three formants of most speakers' speech.

The apical electrodes are stimulated at about 250 cycles/s and the basal electrodes at about 1500 cycles/s. The patient's T and C levels are carefully set

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to ensure that stimulation levels are suitable for the two different rates and adjustments made if necessary. The electrodes to be stimulated are chosen by selecting the eight largest spectral energies within filterbanks derived from the Fast Fourier Transform (FFT) or the Discrete Wavelet Transform (DWT).

5 The values quoted above are examples. Patient-to-patient variability is large and some need higher stimulation rates on the apical electrodes and/or lower stimulation rates on the basal electrodes. These are determined for each individual by evaluating a number of rate combinations in every day usage. Also, some patients do not have as many electrodes available and so the choice
10 of electrodes is altered to suit their situation. However, the spectral ranges of the apical and basal electrodes remain much the same.

By using the Differential Rate Sound Processor (DRSP) program of the invention, features of speech will be more optimally presented to the cochlear implant user leading to improved speech understanding performance.

15 In the implementation of the second aspect of the invention, the software necessary to provide a variable rate of stimulation depending on the incoming speech signal is downloaded to the SPEAR processor and stored on an EPROM.

Patient map details, including frequency bands, threshold (T) levels and comfort (C) levels, are also stored on the device. Monopolar stimulation mode
20 is used to reduce current levels and for longer battery life.

The standard rate of stimulation is about 250 cycles/s and the higher rate is about 1500 cycles/s. The patient's T and C levels are carefully set to ensure that stimulation levels are suitable for the two different rates. The electrodes to be stimulated are chosen by selecting the eight largest spectral energies within
25 filterbanks derived from the Fast Fourier Transform (FFT) or the Discrete Wavelet Transform (DWT).

The changes in spectral energies and the amount of frequency energy are monitored over time. When there is a significantly large change between frames separated by the period of the lower stimulation rate then the higher stimulation

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rate is used for 50 ms. This procedure locates plosive bursts and other rapid spectral changes. The higher stimulation rate is also used when the ratio of energy below about 300Hz to that above about 2000Hz is less than about 0.5. This locates phonemes with significant frication.

- 5 The values quoted above are examples. Patient-to-patient variability is large and some need a higher stimulation rate for the standard rate and/or a lower stimulation rate for the higher rate. These are determined for each individual by evaluating a number of rate combinations in every day usage. Thresholds for changes in energy and ratio of energies are also adjustable for
- 10 each individual.

CLAIMS:

1. A sound processor for a cochlear implant having electrodes for stimulating the auditory nerve, including means for receiving sounds, means for
5 processing the sounds and converting them to electrical stimulation signals for application to the electrodes of the cochlear implant for stimulation of the auditory nerve, said sound processing means including means for generating electrical signals to be applied to the basal electrodes having different predetermined rates of stimulation.
10
2. The sound processor of claim 1, wherein the cochlear implant has one form of the invention, the cochlear implant has basal electrodes and apical electrodes and the means for generating electrical signals to be applied to the apical electrodes have a different rate of stimulation, the electrical signals to be
15 applied to the basal electrodes having a higher rate of stimulation than the electrical signals to be applied to the apical electrodes.
3. The sound processor of claim 2, wherein the more apical electrodes are selected for stimulator signals that represents the voice bar and lower formants
20 of the sounds.
4. The sound processor of claim 3, where the more apical electrodes apply stimulation signals having a stimulation rate of between about 250 cycles per second and about 800 cycles per second depending on the user, to provide
25 precise spectral and place of articulation information.
5. The sound processor of any one of claims 2 to 4, wherein the more basal electrodes apply stimulation signals having a stimulation rate of at or above

about 800 cycles per second depending on the user, to provide precise information about temporal events and friction.

6. The sound processor of any one of claims 2 to 5, including a twenty (20)
5 electrode implant, the apical electrodes are electrodes 0 to 12 and the basal
electrodes are electrodes 13 to 19, the apical electrodes representing sound
frequencies from 0 to about 2700Hz, while the basal electrodes represent
frequencies from about 2700Hz to about 7900Hz, the apical electrode
frequencies, are sufficient to contain the first three formants of most speakers
10 speech.

7. The sound processor of any one of claims 2 to 6, wherein the apical
electrodes are stimulated at about 250 cycles per second while the basal
electrodes are stimulated at about 1500 cycles per second.
15

8. The sound processor of claim 7 wherein the threshold (T) levels and
comfort (C) levels of the patient are carefully set, the electrodes to be stimulated
are chosen by selecting the eight largest spectral energies within filterbanks
derived from the Fast Fourier Transform (FFT) or the Discrete Wavelet
20 Transform (DWT) which is performed by the processor.

9. A sound processor for a cochlear implant having electrodes for
stimulating the auditory nerve, including means for receiving sounds, means for
processing the sounds and converting to electrical stimulation signals for
25 application to the electrodes of the cochlear implant whereby the auditory nerve
is electrically stimulated, said sound processing means having means for varying
the overall rate of stimulation of the electrical stimulation signals depending on
the parameters of the sound received by the sound receiving means.

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10. The sound processor of claim 9, wherein the sound processing means is programmed to continually adjust the rate of stimulation of the electrical stimulation signals depending on the parameters of the incoming speech signal, to this end, the incoming speech signal will be processed to detect events that
5 are better represented using a higher rate of stimulation.

11. The sound processor of claim 9 or 10, as defined in any one of claims 2 to 8.

10 12. The sound processor of any preceding claim, wherein the implant is one which uses pulsatile stimulation.

13. The sound processor of any preceding claim wherein a SPEAR processing device is programmed using the Differential Rate Sound Processor
15 (DRSP) program defined in any preceding claim to optimally present the features of speech to the implant.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 00/01038

A. CLASSIFICATION OF SUBJECT MATTER		
Int Cl ⁷ : H04R 25/00; A61F 2/18		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC: H04R, A61F, A61N		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU: IPC as above		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) DERWENT: cochlear, bionic ear, inside ear, sound, voice, process, electrode, stimulation, excitation JAPIO : same as above INSPEC : same as above		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Journal of the Acoustical Society of America, Volume 98, No. 2, pt. 1 issued August 1995, Sipke Pijl and Dietrich W.F. Schwarz, "Melody recognition and musical interval perception by deaf subjects stimulated with electric pulse trains through single cochlear implant electrodes" Pages 886 - 895	
Y	Whole document US 5271397 A(SELIGMAN et al.), 21 December 1993	1-13
Y	Whole document	1-13
Y	WO 91/03913 A1 (COCHLEAR PTY LIMITED), 21 March 1991 Whole document	1-13
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex		
* Special categories of cited documents: "A" Document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 22 September 2000		Date of mailing of the international search report 29 SEP 2000
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No.: (02) 6285 3929		Authorized officer MANISH RAJ Telephone No.: (02) 6283 2175

INTERNATIONAL SEARCH REPORT

I .national application No.
PCT/AU 00/01038

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Journal of Acoustical Society of America, Volume 98, No. 4, October 1995, David A. Nelson, Dianne J. Van Tasell, Anna C. Schroder, Sigfrid Soli, Samuel Lerine "Electrode ranking of place pitch and speech recognition in electrical hearing", pages 1987-1999.	1
A	Abstract US 5922016 A (WAGNER), 13 July 1999	1-13
A	Whole document	
A	US 5749912 A (ZHANG et al), 12 May 1998	1-13
A	Whole document	

International application No.
PCT/AU 00/01038

Patent Document Cited in Search Report				Patent Family Member			
US	5 271 397	AU	63392/90	CA	2 024 845	EP	450 004
		WO	91/03 913	US	5 095 904		
WO	91/03 913	AU	63392/90	CA	2 024 845	EP	450 004
		US	5 271 397	US	5 095 904		
US	5 749 912	AU	38899/95	US	5 549 658	WO	9 612 456

END OF ANNEX

PATENT COOPERATION TREATY
PCT
INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 40455407 TNB:NB	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. PCT/AU00/01038	International Filing Date (day/month/year) 1 September 2000	Priority Date (day/month/year) 2 September 1999
International Patent Classification (IPC) or national classification and IPC Int. Cl. ⁷ H04R 25/00; A61F 2/18		
Applicant THE BIONIC EAR INSTITUTE et al		

1.	This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2.	This REPORT consists of a total of 3 sheets, including this cover sheet. <input type="checkbox"/> This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT). These annexes consist of a total of sheet(s).
3.	This report contains indications relating to the following items: I <input checked="" type="checkbox"/> Basis of the report II <input type="checkbox"/> Priority III <input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability IV <input type="checkbox"/> Lack of unity of invention V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement VI <input type="checkbox"/> Certain documents cited VII <input type="checkbox"/> Certain defects in the international application VIII <input type="checkbox"/> Certain observations on the international application

Date of submission of the demand 15 March 2001	Date of completion of the report 3 April 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer MANISH RAJ Telephone No. (02) 6283 2175

I. Basis of the report	
1.	<p>With regard to the elements of the international application:*</p> <p><input checked="" type="checkbox"/> the international application as originally filed.</p> <p><input type="checkbox"/> the description, pages , as originally filed, pages , filed with the demand, pages , received on with the letter of</p> <p><input type="checkbox"/> the claims, pages , as originally filed, pages , as amended (together with any statement) under Article 19, pages , filed with the demand, pages , received on with the letter of</p> <p><input type="checkbox"/> the drawings, pages , as originally filed, pages , filed with the demand, pages , received on with the letter of</p> <p><input type="checkbox"/> the sequence listing part of the description: pages , as originally filed pages , filed with the demand pages , received on with the letter of</p>
2.	<p>With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.</p> <p>These elements were available or furnished to this Authority in the following language which is:</p> <p><input type="checkbox"/> the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).</p> <p><input type="checkbox"/> the language of publication of the international application (under Rule 48.3(b)).</p> <p><input type="checkbox"/> the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).</p>
3.	<p>With regard to any nucleotide and/or amino acid sequence disclosed in the international application, was on the basis of the sequence listing:</p> <p><input type="checkbox"/> contained in the international application in written form.</p> <p><input type="checkbox"/> filed together with the international application in computer readable form.</p> <p><input type="checkbox"/> furnished subsequently to this Authority in written form.</p> <p><input type="checkbox"/> furnished subsequently to this Authority in computer readable form.</p> <p><input type="checkbox"/> The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.</p> <p><input type="checkbox"/> The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.</p>
4.	<p><input type="checkbox"/> The amendments have resulted in the cancellation of:</p> <p><input type="checkbox"/> the description, pages</p> <p><input type="checkbox"/> the claims, Nos.</p> <p><input type="checkbox"/> the drawings, sheets/fig.</p>
5.	<p><input type="checkbox"/> This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**</p>
<p>* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).</p> <p>** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report</p>	

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**1. Statement**

Novelty (N)	Claims 1 - 13	YES
	Claims	NO
Inventive step (IS)	Claims 1 - 13	YES
	Claims	NO
Industrial applicability (IA)	Claims 1 - 13	YES
	Claims	NO

2. Citations and explanations (Rule 70.7)

1. Claims 1-13 are novel and involve inventive step because no individual citation or obvious combination of citations disclose a sound processor for a cochlear implant including means for receiving sounds, means for processing sounds and converting them to electrical stimulation signals for application to the electrodes of the cochlear implant and sound processing means including means for generating electrical signals to be applied to the basal electrodes having different predetermined rates of stimulation.

2. Claims 1-13 have industrial applicability because the invention claimed can be made or used in the industry.